Chair of Vibroacoustics of Vehicles and Machines
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Machine Learning for Acoustics
Supervised learning methods: discriminative models

Exercise 1

05.11.2025

Using an ANN to analyze a 1-dof vibration

Experimental data of free vibration of a damped single degree of freedom (DOF) system are given in the file *"vibration_data_ANN.mat"*. It is your task to build an ANN using a Python library of your choice. Furthermore, the predefined Jupyter Lab Script is intended to get started and analyze the network performance by alternating the model parameters.

Since the analytical solution of a free 1-DOF vibration is given as

$$y(t) = e^{-D\omega_0 t}\left(y_0 \cos \omega_d t + \frac{\omega_0 D y_0}{\omega_d} \sin \omega_d t\right), \tag{1}$$

it can be used to quantify the accuracy of the ANN prediction. Assume an initial displacement of $y_0 = 10$, a damping coefficient $D = 0.05$ and a frequency $f = 5\,\mathrm{Hz}$. The angular frequency ω_d and the frequency f are related as $\omega_d = 2\pi f$ and the angular frequency of the damped and undamped system ω_0 are connected via

$$\omega_d = \sqrt{1 - D^2}\,\omega_0. \tag{2}$$

Quantify the performance of the ANN based on the test data set and validate the prediction against the analytic solution.

(a) Open the jupyter lab notebook *"ASSA2025_AI_DiscModels_Exercise_01_Solution"* file and get familiar with the code and the data.

(b) Do the required pre-processing of the data and randomly split the data set into $70\,\%$ training and $30\,\%$ test data.

(c) Implement an ANN with a suitable network architecture. Put special focus on the choice of the activation functions.

(d) Separate in groups and analyze the following parameters and train the ANN with your chosen network architecture and predict the response of the free vibration:

- Group 1: Use the analytical solution to create more data points for the initial training. Investigate the prediction quality using various amount of base data.
- Group 2: Review the Keras documentation and design new network architectures. Investigate each network performance.
- Group 3: Investigate the network performance by varying the epoch size as well as the batch size.
- Group 4: There are other measures for the loss and the metrics. In addition, other optimizers are available. Investigate other options and combinations.
- Group 5: The use of the correct activation functions is key for correct deep neural network application. Investigate other activation functions and the corresponding network performance.

Present you findings in a short presentation.